PHARMACEUTICAL COMBINATION USEFUL FOR STEM CELL MOBILIZATION

FIELD OF THE INVENTION

This invention regards a combination of biologically active molecules for use in the mobilization of blood stem cells in a patient or subject in need thereof. More specifically, the invention provides a combination of G-CSF and PlGF particularly effective in stimulating the mobilization of peripheral blood progenitor cells (PBPCs) thereby increasing feasibility and efficacy of organ or cell transplantation and of chemo-radiotherapy protocols in tumor patients.

BACKGROUND OF THE INVENTION

Autologous PBPCs have significantly increased indications, feasibility and efficacy of high-dose chemo-radiotherapy and autologous stem cell transplantation (SCT)[1,2] in patients with non-Hodgkin lymphoma (NHL),[3] relapsed Hodgkin lymphoma (HL),[4] as well as multiple myeloma (MM).[5]

Allogeneic PBPCs represent the preferred stem cell source for HLA-matched SCT and the unique source for HLA-mismatched allografts[6,7,8,9,10,11] which is a potentially curative therapy for patients with high-risk leukemias lacking an HLA-matched related or unrelated donor, i.e., approximately 40% of the global population of patients who may benefit of allogeneic transplantation.

Protocols used to mobilize autologous PBPCs in cancer patients include the use of myeloid growth factors alone or during recovery from cytotoxic chemotherapy, with the latter approach allowing optimal PBPC mobilization[12,13,14]. Mobilization of allogeneic PBPCs from healthy donors is usually achieved by short courses of recombinant human granulocyte colony-stimulating factor (rhG-CSF) in doses ranging from 10 to

20 μg/kg/day[15,16,17,18].

Cancer patients autografted with ≥5 x 10^6 CD34+ cells/kg experience prompt and durable hematopoietic engraftment, whereas those receiving ≤2 x 10^6 CD34+ cells/kg are at risk for delayed engraftment, engraftment failure or secondary myelodysplasia[19]. Therefore, in the setting of autologous SCT, the availability of adequate amounts of CD34+ cells represents an essential prerequisite. Either due to prior extensive chemo-radiotherapy or disease-related factors, a substantial proportion of chemotherapy naïve (10 to 20%) or relapsed/refractory (30 to 40%) cancer patients fail to mobilize optimal amounts of CD34+ cells[20,21,22].

The collection of adequate numbers of allogeneic CD34+ cells does not represent a critical issue in recipients of HLA-identical transplants; however, 5 to 15% of normal donors experience poor stem cell mobilization and require increased doses of rhG-CSF and multiple apheretic procedures[23,24,25]. Recipients of HLA-mismatched allografting require the reinfusion of "mega" doses of T-lymphocyte-depleted CD34+ cells to prevent graft failure and severe GvHD[26]. Under the standard mobilization regimen, (i.e., a 7 day course of rhG-CSF) donors for HLA-mismatched SCT undergo an average of 4 leukaphereses to collect the target cell dose of CD34+ cells (12 x 10^6 $CD34^+$ cells/kg body weight), with a substantial proportion of donors (20 to 25%) failing to provide the target CD34+ cell dose.

Despite age, sex, schedule of cytokine treatment as well as previous chemo-radiotherapy may affect stem cell mobilization[27,28,29], no specific characteristics have been clearly identified as predictive factors for cytokine mobilization. Therefore, any procedure applicable to cancer patients or normal donors, and capable of increasing the yield of circulating progenitors in the absence of added toxicity, is expected to have a profound impact on the feasibility, toxicity and costs both autologous and allogeneic SCT.

Increased PBPC mobilization might be achieved by using molecules capable of interfering with the mechanism(s) regulating hematopoietic stem cell trafficking, i.e., transmigration through the luminal endothelium to extravascular bone marrow spaces in homing and the reverse in mobilization[30,31,32,33]. One additional approach to enhance PBPC mobilization relies on the use of combinations of cytokines, such as recombinant human (rh) granulocyte-macrophage colony-stimulating factor (rhGM-CSF) plus rhG-CSF[34], interleukin-3 (rhIL-3) plus rhG-CSF or rhGM-CSF[35], and PIXY-321[36]. Finally, enhancement of PBPC mobilization might be achieved by incorporating in the standard mobilization regimen early-acting cytokines, such as stem cell factor (rhSCF)[37,38] of flt-3[39] ligand, capable of expanding marrow progenitors, thus increasing the number of cells susceptible to subsequent mobilization by rhG-CSF.

So far, substitutes or adjuncts to rhG-CSF either failed to substantially improve the mobilization of blood progenitors achieved with rhG-CSF alone, or resulted in a limited improvement outweighed by a substantially increased toxicity.

Placental growth factor (PlGF) is a member of the vascular endothelial growth factor (VEGF) family and functions as an angiogenic amplifier by signaling through VEGF receptor-1 (VEGFR1). Recently, administration of an adenoviral vector expressing human (h) PlGF has been shown to exert complex hematopoietic effects, including enhancement of bone marrow recovery following myelosuppression, and mobilization of hematopoietic progenitors. However, the administration of growth factors following injection of recombinant adenoviral vectors presents several major differences from the direct injection of a purified factor, and might not be predictive of its effects when administered according to the modalities used in the clinical setting.

DESCRIPTION OF THE INVENTION

Due to the relevant clinical impact of any procedure capable to improve

stem cell mobilization, we tested the mobilizing activity of PlGF in animal models allowing to simulate PBPC mobilization as occurring in a clinical situation. Normal BALB/c mice were injected intraperitoneally (IP) for 5 days with either control vehicle (PBS/MSA), rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with either recombinant murine (rm)PlGF (2.5 - 5 μg/d) or recombinant human (rh)PlGF (5 - 10 μg/d). Blood samples were collected 2 hours after the last injection of cytokines and the following parameters were evaluated: white blood cell (WBC) counts, frequency and absolute numbers of colony-forming cells (CFC), absolute numbers of long-term culture-initiating cells (LTC-IC).

The effects of rmPlGF are illustrated in Tables 1 - 4 below. It is evident that rmPlGF injected alone has no effect on the mobilization of WBC, CFC, and LTC-IC. A 5-day injection of rmPlGF (5 μg/d) combined with rhG-CSF significantly increases mobilization of CFC and LTC-IC, as compared to rhG-CSF alone.

Tables 5 - 8 summarize the mobilizing effects of rhPlGF. Again, rhPlGF has no effects on circulating WBC or hematopoietic progenitors when injected alone. In contrast, the combined injection of rhPlGF and rhG-CSF significantly increases mobilization of CFC and LTC-IC, as compared to rhG-CSF alone.

We also tested the mobilizing effects of a 12-day treatment with rhPlGF (10 μg/d) and rhG-CSF (10 μg/d). Mice receiving the 12-day treatment were analyzed on days 5, 8, 10, and 12 of therapy. As compared to rhG-CSF alone, the combined rhPlGF/rhG-CSF treatment significantly increased the frequency and the absolute number of blood CFC at each time-point analyzed in our study (Tables 9 - 11).

In addition, the mobilizing activity of PlGF/G-CSF combinations was tested in a non-human primate model (Rhesus Monkeys). The results obtained

in mice were further confirmed in this animal model. In particular, PlGF/G-CSF combination improved the mobilization of WBCs, CFCs, HPP-CFCs and LTC-ICs, in terms of kinetics, frequency and absolute numbers.

The above-indicated studies have been carried out using procedures and conditions that closely resemble the administration of hematopoietic growth factors to human patients. The results clearly demonstrate the presence of a synergistic effect by hG-CSF and rhPlGF in the mobilization of peripheral blood progenitor cells.

Object of the invention is therefore a combined preparation of G-CSF and PlGF useful for stimulating blood stem cell mobilization in a patient or subject in need thereof. As used herein the terms "patient" and "subject" preferably refer to human individuals, but they may also refer to animals, especially mammals. Examples of states, conditions or diseases that may benefit from the mobilization of blood stem cells include, but are not limited to, organ or cell transplantation and tumor chemo-radiotherapy, in particular autologous[1,2] or allogeneic SCT in patients with NHL, relapsed HL[4], MM[5], or in the recovery phase following myelosuppressive chemotherapy.

The active ingredients of the combined preparation can be simultaneously or separately administered in formulation with pharmaceutically acceptable vehicles and excipients. The parenteral route of administration is preferred. Methods for the preparation of pharmaceutical compositions suitable for parenteral administration are known in the art; details can be found in "Remington: The Science and Practice of Pharmacy", Mack Publishing Co. The amount of active ingredients in the combined preparations according to the invention can be varied depending for instance on the administration route, on the effect sought or condition to be treated, and on the response of the patient. As a general rule, an effective amount of G-CSF and PlGF is able to produce the desired response in terms of blood

stem cell mobilization. The patient/subject response can be monitored during the treatment, e.g. by counting the circulating blood stem cells, and if necessary the dosages can be modified accordingly. In a preferred embodiment of the invention, recombinant hG-CSF and rhPlGF are used in form of injectable solutions supplying a daily amount of the active comprised from 1 to 150, preferably from 5 to 20 μg/kg G-CSF and from 10 to 300, preferably from 20 to 150 μg/kg PlGF.

The following examples further illustrate the invention.

EXAMPLES 1-11 - mobilizing effects of PIGF/G-CSF combination in a mouse model

MATERIALS AND METHODS

Animals. Six- to 8-week-old female BALB/c mice, with body weight of 20 to 25 g, were purchased from Charles River (Milano, Italy, EU). Experimental procedures performed on animals were carried out in accordance with the guidelines of the United Kingdom Coordinating Committee on Cancer Research (UK Coordinating Committee on Cancer Research. UKCCCR guidelines for the welfare of animals in experimental neoplasia. Br. J. Cancer., 58:109-113, 1998.). The mice were injected daily, intraperitoneally (IP), for 5 days with either control vehicle (PBS/MSA), rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with either recombinant murine (rm)PlGF (2.5 - 5 μg/d) or recombinant human (rh)PlGF (5 - 10 μg/d). Each experiment was performed at least on three separate occasions, and three to four mice per group per time point were used.

Cytokines. Recombinant human granulocyte colony-stimulating factor (rhG-CSF, Neupogen®) was from Roche (Milan, Italy, EU); rmPlGF was purchased from R&D Systems Inc., Abingdon, United Kingdom); rhPlGF was provided from Geymonat SpA (Anagni, Italy, EU).

Mobilization protocols. The standard mobilization protocol included

treatment of BALB/c with rhG-CSF (10 μg/mouse, IP) once daily for 5 days. To evaluate the mobilizing effects of PlGF, rmPlGF (2.5 - 5 μg/mouse, IP) or rhPlGF (5 - 10 μg/ mouse, IP) were administered once daily for 5 days either as a single agent or in combination with rhG-CSF. The mobilizing effects of rhPlGF were also tested by a 12-day treatment with rhPlGF (10 μg/mouse/day) and rhG-CSF (10 μg/mouse/day). Controls were injected with PBS/MSA.

Mobilization parameters. Mobilization was evaluated by white blood cell (WBC) counts, frequency and absolute numbers of colony-forming cells (CFC), absolute numbers of long-term culture-initiating cells (LTC-IC). Unless otherwise stated, animals were sacrificed two hours after the last treatment.

Cell harvesting and separation. PB was harvested from the orbital plexus into heparin-containing tubes. After white blood cell (WBC) counting, PB was diluted (1:4, v/v) with PBS and mononuclear cells (MNCs) were separated by centrifugation (280 g, 30 min, room temperature) on a Ficoll discontinuous density gradient. Cells were then washed twice in Iscove's modified Dulbecco's medium (IMDM, Seromed, Berlin, Germany, EU) supplemented with 10% fetal bovine serum (FBS, Stem Cell Technologies, Vancouver, Canada), 2 mM L-glutamine and antibiotics.

WBC counts. WBC counts were performed using heparin-anticoagulated blood and an automated counter (ADVIA 120, Bayer, Milano, Italy, EU).

Colony-forming cell (CFC) assay. Total colony-forming cells (CFCs), i.e., granulocyte-macrophage colony-forming units (CFU-GM), erythroid burst-forming units (BFU-E), and multilineage CFU (CFU-GEMM) were assessed in standard methylcellulose cultures. Briefly, 1-ml aliquots of blood (5 x 10^4 to 2 x 10^5 MNCs) were plated in 35-mm Petri dishes in methylcellulose-based medium (HCC-3434; Stem Cell Technologies) supplemented with recombinant

mouse (rm) stem cell factor (rmSCF, 50 ng/ml), mouse rm interleukin-3 (rmIL-3, 10 ng/ml), recombinant human (rh) interleukin-6 (rhIL-6, 10 ng/ml) and rh erythropoietin (rhEpo, 3 U/ml). Colonies were scored according to standard criteria after 12-14 days of incubation at 37°C in a humidified atmosphere of 5% CO_2 in air (Humphries, R.K.et al., Blood, 53:746-763, 1979.).

Long-term culture-initiating cell (LTC-IC) assay. LTC-IC were assessed in bulk cultures (Carlo-Stella C, et al. Blood. 1999;93:3973-82). Briefly, test cells (5 - 8 x 10^6) were resuspended in complete medium (Myelocult™ 5100, Stem Cell Technologies) and seeded into cultures containing a feeder layer of irradiated (2,000 cGy) murine AFT024 cells (kindly provided by Dr. K. Moore, Princeton University, Princeton, NJ, USA) (Moore KA, et al., Blood. 1997;89:4337-47).

Complete medium consisted of alpha-medium supplemented with FBS (12.5%), horse serum (12.5%), L-glutamine (2 mM), 2-mercaptoethanol (10^{-4} M), inositol (0.2 mM), folic acid (20 μM) plus freshly dissolved hydrocortisone (10^{-6} M). Cultures were fed weekly by replacement of half of the growth medium with fresh complete medium. After 4 weeks in culture, nonadherent cells and adherent cells harvested by trypsinization were pooled, washed, and assayed together for clonogenic cells in methylcellulose cultures. The total number of clonogenic cells (i.e., CFU-GEMM plus BFU-E plus CFU-GM) present in 4-week-old LTC provides a relative measure of the number of LTC-IC originally present in the test suspension. Absolute LTC-IC values were calculated by dividing the total number of clonogenic cells by 4, which is the average output of clonogenic cells per LTC-IC (Sutherland HJ, et al.,Blood. 1989;74:1563-70).

EXAMPLE 1

Table 1 - WBC counts in mice treated with rmPlGF and/or rhG-CSF

Mobilization Regimen*	WBC/μL blood	
	Median (range)	Mean ± SD
PBS/MSA	2,000 (850 - 4,000)	2,165 ± 929
rhG-CSF (10 μg/d)	6,000 (5,200 - 21,650)	9,577 ± 5,575
rmPlGF (5 μg/d)	2,450 (1,350 - 2,950)	2,450 ± 141
rhG-CSF (10 μg/d) + rmPlGF (2.5 μg/d)	5,600 (4,600 - 13,700)	7,040 ± 3,778
rhG-CSF (10 μg/d) + rmPlGF (5 μg/d)	9,500 (4,800 - 18,400)	9,980 ± 5,715

* BALB/c mice were injected IP for 5 days with either PBS/MSA, rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with rmPlGF (2.5 - 5 μg/d). Blood samples were collected 2 hours after the last injection of rmPlGF and/or rhG-CSF.

EXAMPLE 2

Table 2 - Frequency of circulating CFCs in mice treated with rmPlGF and/or rhG-CSF

Mobilization Regimen*	CFCs/10^5 MNCs	
	Median (range)	Mean ± SD
PBS/MSA	7 (2 - 15)	8 ± 3
rhG-CSF (10 μg/d)	76 (51 - 148)	82 ± 29
rmPlGF (5 μg/d)	8 (7 - 9)	8 ± 1
rhG-CSF (10 μg/d) + rmPlGF (2.5 μg/d)	115 (93 - 184)	130 ± 37
rhG-CSF (10 μg/d) + rmPlGF (5 μg/d)	195 (113 - 253)	180 ± 58

* BALB/c mice were injected IP for 5 days with either PBS/MSA, rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with rmPlGF (2.5 - 5 μg/d). Blood samples were collected 2 hours after the last injection of rmPlGF and/or rhG-CSF. CFCs include granulocyte-macrophage CFC

(CFU-GM), erythroid burst-forming unit (BFU-E), and multipotent CFC (CFU-Mix). CFC data are derived from quadruplicate cultures on samples from each animal.

EXAMPLE 3

Table 3 - Absolute number of circulating CFCs in mice treated with rmPlGF and/or rhG-CSF

Mobilization Regimen*	CFCs per ml Blood	
	Median (range)	Mean ± SD
PBS/MSA	57 (9 - 288)	81 ± 75
rhG-CSF (10 μg/d)	3,129 (1,042 - 5,518)	2,977 ± 1,126
rmPlGF (5 μg/d)	96 (87 - 105)	96 ± 13
rhG-CSF (10 μg/d) + rmPlGF (2.5 μg/d)	2,568 (1,480 - 5,885)	3,198 ± 1,928
rhG-CSF (10 μg/d) + rmPlGF (5 μg/d)	6,143 (2,486 - 11,520)	6,015 ± 3,674

* BALB/c mice were injected IP for 5 days with either PBS/MSA, rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with rmPlGF (2.5 - 5 μg/d). Blood samples were collected 2 hours after the last injection of rmPlGF and/or rhG-CSF. CFCs include granulocyte-macrophage CFC (CFU-GM), erythroid burst-forming unit (BFU-E), and multipotent CFC (CFU-Mix). CFC data are derived from quadruplicate cultures on samples from each animal. The absolute number of circulating CFCs in blood is a function of the frequency of CFC multiplied by the total number of MNCs per ml blood.

EXAMPLE 4

Table 4 - Absolute number of circulating LTC-ICs in mice treated with rmPlGF and/or rhG-CSF

Mobilization Regimen*	LTC-ICs per ml Blood	
	Median (range)	Mean ± SD
PBS/MSA	7 (3 - 29)	9 ± 5
rhG-CSF (10 μg/d)	194 (57 - 337)	208 ± 98
rmPlGF (5 μg/d)	4 (3 - 5)	4 ± 2
rhG-CSF (10 μg/d) + rmPlGF (2.5 μg/d)	565 (279 - 852)	565 ± 405
rhG-CSF (10 μg/d) + rmPlGF (5 μg/d)	1,173 (852 - 2,070)	1,365 ± 364

* BALB/c mice were injected IP for 5 days with either PBS/MSA, rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with rmPlGF (2.5 - 5 μg/d). Blood samples were collected 2 hours after the last injection of rmPlGF and/or rhG-CSF. The absolute number of circulating LTC-IC was assayed in bulk cultures. Test cells (5 - 8 x 10^6) were seeded into cultures containing a feeder layer of irradiated murine AFT024 cells. After 4 weeks in culture, nonadherent cells and adherent cells harvested by trypsinization were pooled, washed, and assayed together for clonogenic cells. The total number of clonogenic cells (i.e., CFU-Mix plus BFU-E plus CFU-GM) present in 4-week-old LTC provides a relative measure of the number of LTC-IC originally present in the test suspension. The absolute number of circulating LTC-ICs in blood is a function of the frequency of LTC-ICs multiplied by the total number of MNCs per ml blood.

EXAMPLE 5

Table 5 - WBC counts in mice treated with rhPlGF and/or rhG-CSF

Mobilization Regimen*	WBC/μL blood	
	Median (range)	Mean ± SD
PBS/MSA	2,000 (850 - 4,000)	2,165 ± 929
rhG-CSF (10 μg/d)	6,000 (5,200 - 21,650)	9,577 ± 5,575
rhPlGF (10 μg/d)	1,900 (1,050 - 5,000)	2,296 ± 1,235
rhG-CSF (10 μg/d) + rhPlGF (5 μg/d)	14,400 (11,000 - 14,600)	13,333 ± 2,023
rhG-CSF (10 μg/d) + rhPlGF (10 μg/d)	12,800 (5,100 - 17,350)	11,728 ± 4,968

* BALB/c mice were injected IP for 5 days with either PBS/MSA, rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with rhPlGF (5 - 10 μg/d). Blood samples were collected 2 hours after the last injection of rmPlGF and/or rhG-CSF.

EXAMPLE 6

Table 6 - Frequency of circulating CFCs in mice treated with rhPlGF and/or rhG-CSF

Mobilization Regimen*	CFCs/10^5 MNCs	
	Median (range)	Mean ± SD
PBS/MSA	7 (2 - 15)	8 ± 3
rhG-CSF (10 μg/d)	76 (51 - 148)	82 ± 29
rhPlGF (10 μg/d)	9 (6 - 21)	10 ± 4
rhG-CSF (10 μg/d) + rhPlGF (5 μg/d)	228 (208 - 237)	224 ± 14
rhG-CSF (10 μg/d) + rhPlGF (10 μg/d)	264 (111 - 384)	256 ± 77

* BALB/c mice were injected IP for 5 days with either PBS/MSA, rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with rmPlGF (2.5 - 5 μg/d). Blood samples were collected 2 hours after the last injection of rmPlGF and/or rhG-CSF. CFCs include granulocyte-macrophage CFC

(CFU-GM), erythroid burst-forming unit (BFU-E), and multipotent CFC (CFU-Mix). CFC data are derived from quadruplicate cultures on samples from each animal.

EXAMPLE 7

Table 7 - Absolute number of circulating CFCs in mice treated with rhPlGF and/or rhG-CSF

Mobilization Regimen*	CFCs per ml Blood	
	Median (range)	Mean ± SD
PBS/MSA	57 (9 - 288)	81 ± 75
rhG-CSF (10 μg/d)	3,129 (1,042 - 5,518)	2,977 ± 1,126
rhPlGF (10 μg/d)	74 (12 - 236)	82 ± 64
rhG-CSF (10 μg/d) + rhPlGF (5 μg/d)	9,467 (7,514 - 11,325)	9,435 ± 1,906
rhG-CSF (10 μg/d) + rhPlGF (10 μg/d)	11,584 (8,105 - 17,408)	12,122 ± 2,788

* BALB/c mice were injected IP for 5 days with either PBS/MSA, rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with rmPlGF (2.5 - 5 μg/d). Blood samples were collected 2 hours after the last injection of rmPlGF and/or rhG-CSF. CFCs include granulocyte-macrophage CFC (CFU-GM), erythroid burst-forming unit (BFU-E), and multipotent CFC (CFU-Mix). CFC data are derived from quadruplicate cultures on samples from each animal. The absolute number of circulating CFCs in blood is a function of the frequency of CFC multiplied by the total number of MNCs per ml blood.

EXAMPLE 8

Table 8 - Absolute number of circulating LTC-ICs in mice treated with rhPlGF and/or rhG-CSF

Mobilization Regimen*	LTC-ICs per ml Blood	
	Median (range)	Mean ± SD
PBS/MSA	7 (3 - 29)	9 ± 5
rhG-CSF (10 μg/d)	194 (57 - 337)	208 ± 98
rhPlGF (10 μg/d)	ND	ND
rhG-CSF (10 μg/d) + rhPlGF (5 μg/d)	ND	ND
rhG-CSF (10 μg/d) + rhPlGF (10 μg/d)	1,776 (1,407 - 1,990)	1,724 ± 294

ND, not done

* BALB/c mice were injected IP for 5 days with either PBS/MSA, rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with rmPlGF (2.5 - 5 μg/d). Blood samples were collected 2 hours after the last injection of rmPlGF and/or rhG-CSF. The absolute number of circulating LTC-IC was assayed in bulk cultures. Test cells (5 - 8 x 10^6) were seeded into cultures containing a feeder layer of irradiated murine AFT024 cells. After 4 weeks in culture, nonadherent cells and adherent cells harvested by trypsinization were pooled, washed, and assayed together for clonogenic cells. The total number of clonogenic cells (i.e., CFU-Mix plus BFU-E plus CFU-GM) present in 4-week-old LTC provides a relative measure of the number of LTC-IC originally present in the test suspension. The absolute number of circulating LTC-ICs in blood is a function of the frequency of LTC-ICs multiplied by the total number of MNCs per ml blood.

EXAMPLE 9

Table 9 - WBC counts in mice receiving a 12-day treatment with rhPlGF (10 μg/d) and/or rhG-CSF (10 μg/d)

Mobilization Regimen*	WBC/μL blood
	Mean ± SD
PBS/MSA	2,165 ± 929
5-day rhG-CSF	18,683 ± 3,001
5-day rhG-CSF + rhPlGF	16,083 ± 1,227
8-day rhG-CSF	22,017 ± 5,778
8-day rhG-CSF + rhPlGF	16,000 ± 6,354
10-day rhG-CSF	21,500 ± 3,317
10-day rhG-CSF + rhPlGF	24,800 ± 6,699
12-day rhG-CSF	43,100 ± 8,598
12-day rhG-CSF + rhPlGF	46,167 ± 5,678

* BALB/c mice were injected IP for 12 days with either PBS/MSA, rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with rhPlGF (10 μg/d). Blood samples were collected after 5, 8, 10, and 12 days of treatment.

EXAMPLE 10

Table 10 - Frequency of circulating CFCs in mice receiving a 12-day treatment with rhPlGF (10 μg/d) and/or rhG-CSF (10 μg/d)

Mobilization Regimen*	CFCs/10^5 MNCs
	Mean ± SD
PBS/MSA	8 ± 3
5-day rhG-CSF	63 ± 12
5-day rhG-CSF + rhPlGF	297 ± 80
8-day rhG-CSF	70 ± 5
8-day rhG-CSF + rhPlGF	180 ± 20
10-day rhG-CSF	102 ± 8
10-day rhG-CSF + rhPlGF	274 ± 34
12-day rhG-CSF	106 ± 19
12-day rhG-CSF + rhPlGF	299 ± 49

* BALB/c mice were injected IP for 12 days with either PBS/MSA, rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with rhPlGF (10 μg/d). Blood samples were collected after 5, 8, 10, and 12 days of treatment. CFCs include granulocyte-macrophage CFC (CFU-GM), erythroid burst-forming unit (BFU-E), and multipotent CFC (CFU-Mix). CFC data are derived from quadruplicate cultures on samples from each animal.

EXAMPLE 11

Table 11 - Absolute number of circulating CFCs in mice receiving a 12-day treatment with rhPlGF (10 μg/d) and/or rhG-CSF (10 μg/d)

Mobilization Regimen*	CFCs per ml Blood
	Mean ± SD
PBS/MSA	81 ± 75
5-day rhG-CSF	3,427 ± 232
5-day rhG-CSF + rhPlGF	11,649 ± 1,827
8-day rhG-CSF	6,361 ± 1,931
8-day rhG-CSF + rhPlGF	10,341 ± 799
10-day rhG-CSF	4,335 ± 923
10-day rhG-CSF + rhPlGF	14,104 ± 2,687
12-day rhG-CSF	10,968 ± 2,183
12-day rhG-CSF + rhPlGF	32,024 ± 4,915

* BALB/c mice were injected IP for 12 days with either PBS/MSA, rhG-CSF alone (10 μg/d), or a combination of rhG-CSF (10 μg/d) with rhPlGF (10 μg/d). Blood samples were collected after 5, 8, 10, and 12 days of treatment. CFCs include granulocyte-macrophage CFC (CFU-GM), erythroid burst-forming unit (BFU-E), and multipotent CFC (CFU-Mix). CFC data are derived from quadruplicate cultures on samples from each animal. The absolute number of circulating CFCs in blood is a function of the frequency of CFC multiplied by the total number of MNCs per ml blood.

EXAMPLES 12-18 - mobilizing effects of PlGF/G-CSF combination in a non-human primate model

MATERIALS AND METHODS

Experimental design. A cohort of Rhesus Monkeys (n = 4) was initially mobilized with G-CSF alone (100 μg/kg/day, SC, for 5 days) (**cycle 1**), and after a 6-week wash-out period, received a second mobilization

therapy consisting of rhPlGF (130 μg/kg, IV, for 5 days) plus rhG-CSF (100 μg/kg/day, SC, for 5 days) (**cycle 2**). After an additional 6-week wash-out period, a third mobilization cycle consisting of rhPlGF (260 μg/kg, IV, for 5 days) plus rhG-CSF (100 μg/kg/day, SC, for 5 days) (**cycle 3**) was administered to the same cohort of monkeys. According to the study designs, the kinetics of mobilization following cycle 1 served as intra-monkey control to assess the mobilization following cycles 2 and 3.

Mobilization parameters. We analyzed the mobilization kinetics of white blood cells (WBCs), as well as frequency and absolute numbers of committed colony-forming cells (CFCs), high-proliferative potential progenitors (HPP-CFCs), and long-term culture-initiating cells (LTC-ICs). Mobilization parameters were analyzed daily during treatment (days 1 to 5), and 3 and 5 days post-cessation of therapy. Peripheral blood samples were obtained from the femoral vein of anesthetized primates (ketamin, 10 mg/kg, intramuscularly) using aseptic techniques.

WBC counts. WBC counts were performed using EDTA-anticoagulated blood and an automated counter (ADVIA 120, Bayer, Milano, Italy, EU).

CFC and HPP-CFC assays. Total CFCs [i.e., granulocyte-macrophage colony-forming units (CFU-GM), erythroid burst-forming units (BFU-E), and multilineage (granulocyte, erythrocyte, macrophage, megakaryocyte) CFU (CFU-GEMM)] and HPP-CFCs were assayed by using heparinized blood according to a previously described technique (41, 42). Briefly, mononuclear cells (MNCs) obtained by centrifugation on a Ficoll discontinuous gradient (density = 1.077 g/ml) were plated (1×10^4 to 2×10^5 per ml) in quadruplicate in 35-mm Petri dishes in methylcellulose-based medium (HCC-4100, Stem Cell Technologies, Vancouver, Canada) supplemented with recombinant human stem cell factor (rhSCF, 50 ng/ml, Stem Cell Technologies), interleukin-3 (rhIL-3, 20 ng/ml, Stem Cell Technologies), interleukin-6

(rhIL-6, 20 ng/ml, Stem Cell Technologies), rhG-CSF (20 ng/ml, Stem Cell Technologies), granulocyte-macrophage colony-stimulating factor (rhGM-CSF, 20 ng/ml, Stem Cell Technologies), and erythropoietin (rhEpo, 3 U/ml, R&D Systems Inc., Abingdon, United Kingdom). CFCs were scored after 12-14 days of incubation (37°C, 5% CO_2) according to standard criteria. HPP-CFCs, defined as macroscopically visible colonies of >1 mm in diameter of compact colony growth, were scored after 28 days of incubation from methylcellulose cultures supplemented with rhSCF (50 ng/ml), rhIL-3 (20 ng/ml), rhIL-6 (20 ng/ml), rhG-CSF (20 ng/ml), rhGM-CSF (20 ng/ml), and rhEpo (3 U/ml) (43). The absolute number of circulating CFCs or HPP-CFCs in blood is a function of the frequency of CFCs or HPP-CFCs multiplied by the total number of MNCs per ml blood.

LTC-IC assays. The frequency of LTC-ICs was assessed under limiting dilution conditions (44). Briefly, serial dilutions of test cells (2×10^5 to 3×10^3) were resuspended in 150 µL complete medium (Myelocult™ 5100, Stem Cell Technologies) consisting of alpha-medium supplemented with fetal bovine serum (12.5%), horse serum (12.5%), L-glutamine (2 mM), 2-mercaptoethanol (10^{-4} M), inositol (0.2 mM), folic acid (20 µM) plus freshly dissolved hydrocortisone (10^{-6} M) and plated in 96-well flat-bottom plates. For each test cell dose, 16 to 22 replicates were plated. Test cells were seeded into plates containing a feeder layer of irradiated (8,000 cGy) murine M2-10B4 cells (3×10^4/cm2, kindly provided by Dr. C. Eaves, Terry Fox Laboratory, Vancouver, Canada) engineered by retroviral gene transfer to produce human IL-3 and G-CSF (45). Cultures were fed weekly by replacement of half of the growth medium with fresh complete medium. After 5 weeks in culture, nonadherent and adherent cells from individual wells were harvested by trypsinization, washed and assayed together for the growth of CFCs. After 12 to 14 days of incubation, cultures were scored as positive

(≥1 colony) or negative (no colony) and the LTC-IC frequencies were calculated by using L-Calc software (Stem Cell Technologies). The absolute numbers of circulating LTC-IC were assessed in bulk cultures (46). Briefly, test cells (5 - 8 x 10^6) were resuspended in complete medium and seeded into cultures containing a feeder layer of irradiated murine M2-10B4 cells (3 x $10^4/cm^2$). After 5 weeks in culture, nonadherent cells and adherent cells harvested by trypsinization were pooled, washed, and assayed together for clonogenic cells. The total number of clonogenic cells (i.e., CFU-GEMM plus BFU-E plus CFU-GM) present in 5-week-old LTC provides a relative measure of the number of LTC-IC originally present in the test suspension. Absolute LTC-IC values were calculated by dividing the total number of clonogenic cells by 4, which is the average output of clonogenic cells per LTC-IC.

EXAMPLE 12

Circulating WBCs. A 5-day administration of rhG-CSF alone induced an average 5-fold increment in the mean (±SD) numbers of WBCs, as compared to pretreatment values. Addition of 130 or 260 µg/kg rhPlGF to rhG-CSF resulted in a modest increase of WBC values detected on day 5 of treatment.

Table 12 - WBC counts in Rhesus monkeys treated with rhG-CSF alone or rhPlGF plus rhG-CSF

	WBC counts per μL blood *		
	Cycle 1	**Cycle 2**	**Cycle 3**
Day	rhG-CSF (100 μg/kg/day, SC, for 5 days)	rhPlGF (130 μg/kg, IV, for 5 days) + rhG-CSF (100 μg/kg/day, SC, for 5 days)	rhPlGF (260 μg/kg, IV, for 5 days) + rhG-CSF (100 μg/kg/day, SC, for 5 days)
1	8,708 ± 2,458	13,498 ± 5,514	8,370 ± 1,585
2	31,313 ± 3,889	24,533 ± 2,789	41,180 ± 7,364
3	40,600 ± 6,274	35,388 ± 2,207	44,085 ± 6,588
4	43,055 ± 6,562	39,440 ± 6,744	37,960 ± 3,598
5	43,523 ± 13,790	60,040 ± 9,508	49,048 ± 7,120
8	14,363 ± 4,163	23,073 ± 9,017	17,783 ± 5,964
10	12,145 ± 5,421	16,398 ± 8,314	11,150 ± 2,915

* Rhesus monkeys (n = 4) received three mobilization cycles separated by a 6-week washout period. Mobilization was elicited at cycle 1 by rhG-CSF alone (100 μg/kg/day, SC, day 1 - 5), at cycle 2 by a combination of rhPlGF (130 μg/kg, IV, day 1 - 5) plus rhG-CSF (100 μg/kg/day, SC, day 1 -5), and at cycle 3 by a combination of rhPlGF (260 μg/kg, IV, day 1 - 5) plus rhG-CSF (100 μg/kg/day, SC, day 1 -5). WBC counts were analyzed daily during treatment (days 1 to 5), as well as 3 and 5 days post-cessation of therapy. Data are expressed as mean ± SD.

EXAMPLE 13

Frequency of CFCs. As compared to baseline values, the mean frequencies of blood CFCs (per 10^5 MNCs) detected at peak were increased by 19-, 53-, and 52-fold under rhG-CSF alone, rhG-CSF/rhPlGF (130 μg/kg), and

rhG-CSF/rhPlGF (260 μg/kg), respectively. As compared to rhG-CSF alone, the combined rhPlGF/rhG-CSF treatment induced a 2-fold increase of CFC frequency on the day of peak.

Table 13 - Frequency of circulating CFCs in Rhesus monkeys treated with rhG-CSF alone or rhPlGF plus rhG-CSF

	CFCs/10^5 MNCs *		
	Cycle 1	**Cycle 2**	**Cycle 3**
Day	rhG-CSF (100 μg/kg/day, SC, for 5 days)	rhPlGF (130 μg/kg, IV, for 5 days) + rhG-CSF (100 μg/kg/day, SC, for 5 days)	rhPlGF (260 μg/kg, IV, for 5 days) + rhG-CSF (100 μg/kg/day, SC, for 5 days)
1	6 ± 1	4 ± 1	5 ± 3
2	4 ± 2	9 ± 1	19 ± 8
3	9 ± 1	39 ± 13	48 ± 26
4	114 ± 51	213 ± 87	245 ± 151
5	63 ± 26	196 ± 26	261 ± 83
8	66 ± 11	40 ± 11	60 ± 39
10	10 ± 7	19 ± 10	21 ± 18

* Rhesus monkeys (n = 4) received three mobilization cycles separated by a 6-week washout period. Mobilization was elicited at cycle 1 by rhG-CSF alone (100 μg/kg/day, SC, day 1 - 5), at cycle 2 by a combination of rhPlGF (130 μg/kg, IV, day 1 - 5) plus rhG-CSF (100 μg/kg/day, SC, day 1 -5), and at cycle 3 by a combination of rhPlGF (260 μg/kg, IV, day 1 - 5) plus rhG-CSF (100 μg/kg/day, SC, day 1 -5). CFCs were analyzed daily during treatment (days 1 to 5), as well as 3 and 5 days post-cessation of therapy. Data are expressed as mean ± SD. CFCs include granulocyte-macrophage CFC (CFU-GM), erythroid burst-forming unit (BFU-E), and multipotent CFC

(CFU-Mix). CFC data are derived from quadruplicate cultures on samples from each animal.

EXAMPLE 14

Absolute values of CFCs. Absolute numbers of circulating CFCs in blood were calculated as a function of the frequency of CFCs multiplied by the total number of MNCs per ml blood. As compared to baseline values, treatment with rhG-CSF alone, rhG-CSF/rhPlGF (130 μg/kg), and rhG-CSF/rhPlGF (260 μg/kg) resulted in a 85- 335- and 358-fold increase of CFCs, respectively. At cycles 2 and 3, the peak levels of CFCs were increased by 4- and 5-fold over cycle 1 (rhG-CSF alone).

Table 14 - Absolute numbers of circulating CFCs in Rhesus Monkeys treated with rhG-CSF alone or rhPlGF plus rhG-CSF

	CFCs per ml blood *		
	Cycle 1	**Cycle 2**	**Cycle 3**
Day	rhG-CSF(100 μg/kg/day, SC, for 5 days)	rhPlGF (130 μg/kg, IV, for 5 days) + rhG-CSF (100 μg/kg/day, SC, for 5 days)	rhPlGF (260 μg/kg, IV, for 5 days) + rhG-CSF (100 μg/kg/day, SC, for 5 days)
1	134 ± 9	138 ± 38	170 ± 129
2	344 ± 207	724 ± 254	6,552 ± 4,365
3	472 ± 60	6,420 ± 4,775	9,634 ± 7,006
4	11,406 ± 4,093	32,347 ± 14,206	53,002 ± 25,250
5	5,397 ± 3,074	46,283 ± 8,287	60,777 ± 8,563
8	3,952 ± 2,666	4,532 ± 3,714	3,719 ± 1,899
10	224 ± 164	448 ± 168	943 ± 994

* Rhesus monkeys (n = 4) received three mobilization cycles separated by a 6-week washout period. Mobilization was elicited at cycle 1 by rhG-CSF

alone (100 μg/kg/day, SC, day 1 - 5), at cycle 2 by a combination of rhPlGF (130 μg/kg, IV, day 1 - 5) plus rhG-CSF (100 μg/kg/day, SC, day 1 -5), and at cycle 3 by a combination of rhPlGF (260 μg/kg, IV, day 1 - 5) plus rhG-CSF (100 μg/kg/day, SC, day 1 -5). CFCs were analyzed daily during treatment (days 1 to 5), as well as 3 and 5 days post-cessation of therapy. Data are expressed as mean ± SD. CFCs include granulocyte-macrophage CFC (CFU-GM), erythroid burst-forming unit (BFU-E), and multipotent CFC (CFU-Mix). CFC data are derived from quadruplicate cultures on samples from each animal. The absolute number of circulating CFCs in blood is a function of the frequency of CFC multiplied by the total number of MNCs per ml blood.

EXAMPLE 15

Frequency of HPP-CFCs. As compared to baseline values, the mean frequencies of blood HPP-CFCs (per 10^5 MNCs) detected on day 5 of mobilization were increased by 5-, and 12-fold under rhG-CSF alone or rhG-CSF/rhPlGF (130 μg/kg), respectively. As compared to rhG-CSF alone, the combined rhPlGF/rhG-CSF treatment induced a 2-fold increase of HPP-CFC frequency on the day of peak.

Table 15 - Frequency of circulating HPP-CFCs in Rhesus monkeys treated with rhG-CSF alone or rhPlGF plus rhG-CSF

	HPP-CFCs/10^5 MNCs *	
	Cycle 1	**Cycle 2**
Day	rhG-CSF (100 µg/kg/day, SC, for 5 days)	rhPlGF (130 µg/kg, IV, for 5 days) + rhG-CSF (100 µg/kg/day, SC, for 5 days)
1	4 ± 1	3 ± 1
2	6 ± 1	3 ± 1
3	13 ± 4	11 ± 3
4	15 ± 4	27 ± 10
5	20 ± 9	37 ± 8
8	18 ± 6	6 ± 4
10	6 ± 1	5 ± 4

* Rhesus monkeys (n = 4) received three mobilization cycles separated by a 6-week washout period. Mobilization was elicited at cycle 1 by rhG-CSF alone (100 µg/kg/day, SC, day 1 - 5), at cycle 2 by a combination of rhPlGF (130 µg/kg, IV, day 1 - 5) plus rhG-CSF (100 µg/kg/day, SC, day 1 -5), and at cycle 3 by a combination of rhPlGF (260 µg/kg, IV, day 1 - 5) plus rhG-CSF (100 µg/kg/day, SC, day 1 -5). HPP-CFCs were analyzed daily during treatment (days 1 to 5), as well as 3 and 5 days post-cessation of therapy. Data are expressed as mean ± SD. HPP-CFC data are derived from quadruplicate cultures on samples from each animal.

EXAMPLE 16

Absolute values of HPP-CFCs. The absolute number of HPP-CFCs per ml blood detected on day 5 of rhG-CSF therapy was 17-fold higher than pre-treatment values. Monkeys receiving the combined rhG-CSF/rhPlGF (130

μg/kg) treatment showed a 158-fold increase of HPP-CFCs as compared to baseline values. At cycle 2, the level of day-5 HPP-CFCs was increased by 5-fold over cycle 1.

Table 16 - Absolute numbers of circulating HPP-CFC in Rhesus Monkeys treated with rhG-CSF alone or rhPlGF plus rhG-CSF

	HPP-CFCs per ml blood *	
	Cycle 1	**Cycle 2**
Day	rhG-CSF (100 μg/kg/day, SC, for 5 days)	rhPlGF (130 μg/kg, IV, for 5 days) + rhG-CSF (100 μg/kg/day, SC, for 5 days)
1	96 ± 17	54 ± 49
2	493 ± 218	258 ± 34
3	683 ± 155	1,709 ± 989
4	1,521 ± 332	3,883 ± 1,309
5	1,593 ± 405	8,557 ± 1,142
8	998 ± 541	603 ± 384
10	121 ± 52	121 ± 87

* Rhesus monkeys (n = 4) received three mobilization cycles separated by a 6-week washout period. Mobilization was elicited at cycle 1 by rhG-CSF alone (100 μg/kg/day, SC, day 1 - 5), at cycle 2 by a combination of rhPlGF (130 μg/kg, IV, day 1 - 5) plus rhG-CSF (100 μg/kg/day, SC, day 1 -5), and at cycle 3 by a combination of rhPlGF (260 μg/kg, IV, day 1 - 5) plus rhG-CSF (100 μg/kg/day, SC, day 1 -5). HPP-CFC counts were analyzed daily during treatment (days 1 to 5), as well as 3 and 5 days post-cessation of therapy. Data are expressed as mean ± SD. HPP-CFCs data are derived from quadruplicate cultures on samples from each animal. The absolute number of circulating HPP-CFCs in blood is a function of the frequency of HPP-CFCs multiplied by

the total number of MNCs per ml blood.

EXAMPLE 17

Frequency of LTC-ICs. Analysis of the LTC-IC frequency by a limiting dilution assay showed that the combined administration of rhPlGF (130 μg/kg) and rhG-CSF resulted in an average increase the LTC-IC frequency by 11-fold (1 in 5,829 vs 1 in 64,064 cells), as compared to rhG-CSF alone.

Table 17 - Frequency of circulating LTC-ICs in Rhesus Monkeys receiving a 5-day course of rhG-CSF alone or rhPlGF plus rhG-CSF

Animal No.	Mobilization Regimen	LTC-IC Frequency (mean)*	95% CI		LTC-IC per 10^5 MNCs
			Lower Frequency	Upper Frequency	
1	rhG-CSF	1/84,265	1/69,209	1/102,598	1.2
2	rhG-CSF	1/65,835	1/54,341	1/79,761	1.5
3	rhG-CSF	ne **	ne	ne	ne
4	rhG-CSF	1/42,091	1/34,837	1/50,854	2.4
1	rhPlGF (130 μg/kg) + rhG-CSF	1/4,009	1/5,977	1/2,689	24.9
2	rhPlGF (130 μg/kg) + rhG-CSF	1/7,562	1/11,100	1/5,152	13.2
3	rhPlGF (130 μg/kg) + rhG-CSF	ne	ne	ne	ne
4	rhPlGF (130 μg/kg) + rhG-CSF	1/5,916	1/8,725	1/4,011	16.9

* The frequency of LTC-IC was assayed under limiting dilution conditions using the murine M2-10B4 cell line as stromal layer. Blood samples were collected on day 5 of mobilization therapy. Serial dilutions of test cells (2×10^5 to 3×10^3) were cultured for 5 weeks and 16 to 22 replicates were plated for each test cell dose. After 5 weeks, nonadherent and adherent

cells from individual wells were assayed for clonogenic cells and the LTC-IC frequencies were calculated using Poisson statistics and the method of maximum likelihood.

EXAMPLE 18

Absolute values of LTC-ICs. Under rhG-CSF alone, absolute numbers of circulating LTC-ICs were increased by 53-fold on day 4 of treatment as compared to baseline values. The combined rhG-CSF/rhPlGF (130 µg/kg) treatment increased LTC-ICs by 389-fold as compared to pretreatment values, and by 15-fold as compared to rhG-CSF alone.

Table 18 - Absolute numbers of circulating LTC-ICs in Rhesus Monkeys treated with rhG-CSF alone or rhPlGF plus rhG-CSF

	LTC-ICs per ml blood *	
	Cycle 1	**Cycle 2**
Day	rhG-CSF (100 µg/kg/day, SC, for 5 days)	rhPlGF (130 µg/kg, IV, for 5 days) + rhG-CSF (100 µg/kg/day, SC, for 5 days)
1	4 ± 7	8 ± 5
2	92 ± 43	56 ± 20
3	111 ± 30	624 ± 340
4	211 ± 41	742 ± 176
5	130 ± 25	3,115 ± 988
8	63 ± 22	533 ± 270
10	6 ± 2	112 ± 40

* Rhesus monkeys (n = 4) received three mobilization cycles separated by a 6-week washout period. Mobilization was elicited at cycle 1 by rhG-CSF alone (100 µg/kg/day, SC, day 1 - 5), at cycle 2 by a combination of rhPlGF (130 µg/kg, IV, day 1 - 5) plus rhG-CSF (100 µg/kg/day, SC, day 1 -5), and at

cycle 3 by a combination of rhPlGF (260 μg/kg, IV, day 1 - 5) plus rhG-CSF (100 μg/kg/day, SC, day 1 -5). LTC-IC counts were analyzed daily during treatment (days 1 to 5), as well as 3 and 5 days post-cessation of therapy. Data are expressed as mean ± SD derived from quadruplicate cultures on samples from each animal at each time point. The absolute number of circulating LTC-IC was assayed in bulk cultures. Test cells (5 - 8 x 10^6) were seeded into cultures containing a feeder layer of irradiated murine M2-10B4 cells. After 5 weeks in culture, nonadherent cells and adherent cells harvested by trypsinization were pooled, washed, and assayed together for clonogenic cells. The total number of clonogenic cells (i.e., CFU-Mix plus BFU-E plus CFU-GM) present in 5-week-old LTC provides a relative measure of the number of LTC-IC originally present in the test suspension. The absolute number of circulating LTC-ICs in blood is a function of the frequency of LTC-ICs multiplied by the total number of MNCs per ml blood.

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